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# Capability Gap Assessment
## Blending Warfighter Experience with Science

## Technical Report

TRADOC Analysis Center
255 Sedgwick Avenue
Fort Leavenworth, KS 66027-2345

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## Blending Warfighter Experience with Science
## Technical Report

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# Chapter 1
# Introduction

**Purpose.**

The U.S. Army Training and Doctrine Command (TRADOC) Analysis Center (TRAC) faces critical issues while supporting requirements generation and acquisition studies for the Department of the Army (DA) and the Department of Defense. Decision makers are asking:

- How much military capability is good enough?
- Is there a capability gap?
- What is the operational impact of the capability gap?
- Is the capability gap mitigated?
- If so, by how much?

To address these questions, TRAC developed a gap assessment approach that blends warfighter experience with science. This paper describes the process, challenges, and opportunities associated with this technique.

**Key Terms.**

- capability gap (or gap) – The inability to execute a specified course of action. The gap may be the result of no existing capability, a lack of proficiency or sufficiency in an existing capability solution, or the need to replace an existing capability solution to prevent a future gap.[1]
- alternatives – Solutions that mitigate gaps.
- attribute –A quantifiable system characteristic. In this case it represents the system characteristics that enable measurement of capability gaps.
- metric – The standard or range of feasible values associated with an attribute.
- qualitative gap – A capability gap that does not have a quantifiable attribute, or has a quantifiable attribute in which technical, performance, or operational study data are unavailable.
- quantitative gap – A capability gap that has a quantifiable attribute and associated technical, performance, or operational study data available for the comparison of alternatives.
- mission impact scale – Developed for each quantifiable attribute, the mission impact scale takes warfighter inputs to establish severity of impact to missions for the feasible values of the associated attribute.
- alternative assessment scale – The results of taking a mission impact scale and placing the appropriate technical, performance, or operational performance data on the scale for each alternative.

[1] Chairman of the Joint Chiefs of Staff Instruction 3170.01H, Joint Capabilities Integration and Development System. 10 January 2012.

- gap assessment scale – A normalized scale across all attributes associated with a single gap.
- overall gap mitigation scale – A roll-up of all gap assessment scales with normalized input for each study alternative.
- "good enough" – A point at which warfighters assess that they can sufficiently complete their mission without significant risk.
- "optimal" – A warfighter's ideal operating value that allows completion of the mission without setbacks or hardships.

**Background.**

TRAC has applied many methods to assess capability gaps. These methods have been grounded in various uses of Army Field Manual (FM) 5-19, Composite Risk Management (CRM). These CRM methods have been used to assess capability gaps' operational risk and/or risk mitigation using a likelihood and severity assessment. Most of these methods, however, have been qualitative in nature, purely based in warfighter opinion. As a qualitative assessment, these previous methods provide potential for warfighters to support new and emerging technologies and systems without regard for what is sufficient in an operational environment.

As funding constraints loom, this new gap assessment approach provides a mathematical method grounded in warfighter experience. This new approach may be used to 1) address key decision maker issues, 2) identify trade space for requirements, and 3) either help develop or corroborate system requirements for capability documents.

The method that this technical report describes was first implemented in the Ground Combat Vehicle (GCV) Analysis of Alternatives (AoA) Milestone B analysis in 2012.

**Relevant Applications.**

- Provide a foundation to identify how much capability is "good enough" to drive requirements development and may be implemented at multiple points throughout the Joint Capabilities Integration and Development System (JCIDS) and Defense Acquisition System. Note that the effect of the approach is greater and more beneficial the earlier it is implemented in the JCIDS/acquisition process.
- Corroborate or help refine capability requirements.
- Identify potential trade space in requirements and capability attributes.
- Assess the operational impact or operational risk of capability gaps and associated attributes.
- Identify to what degree potential solutions mitigate the gap.

**Constraints, Limitations, Assumptions.**

<u>Constraints.</u>

The resources available to execute the analysis constrain this gap assessment. Study time constraints led to the development of this approach, because most of the work can be accomplished before data availability on the potential gap solutions or study alternatives.

Availability of approved and refined gaps can also constrain this process. Regardless of the study and the robustness of the capability gaps, refinement is always required to focus those capability gaps on the measurable attributes of the potential solutions or study alternatives being compared for gap mitigation.

Limitations.
When implementing this approach for a specific subject or study, the data and expert/warfighter availability will be limited.

Assumptions.
The reader has a basic understanding of JCIDS, the Defense Acquisition System, and TRADOC organizational structure.

**Approach.**
This new approach to gap assessment blends warfighter expertise with quantifiable analysis through a scientific approach (figure 1). The most critical step, always executed at the start of the analysis, is identifying and refining the capability gaps. Capability gaps must be refined to contain as much detail as possible, which provides the basis for a more quantitative assessment.

Identifying data sources for the gaps is accomplished in a measurement space[2] workshop. An opportunity follows to survey experienced warfighters about mission impacts of the gaps. For qualitative gaps, warfighters may be asked many questions. For gaps assessed through the new quantitative approach, warfighters are asked to identify the mission impact for the measureable attributes of each capability gap. A mathematical approach is then applied to combine warfighter responses into a single mission impact scale for each capability gap.

When paired with technical, performance, and operational effectiveness data, the mission impact scales enable the analyst to quantifiably assess gap mitigation of potential alternatives against the current capability. All quantifiable gaps may then be rolled up into a single scale to identify the alternative that best mitigates the gap.

Sensitivity analysis may be performed on the quantitative gaps. This may be followed by integration with the qualitative gap assessment and other study results, such as operational effectiveness analyses.

**Organization.** Figure 1 depicts the organization of this report. Following this introduction, Chapter 2, Gap Refinement and Measurement Space, describes the challenging process of identifying and refining the capability gaps requiring analysis. This may be an iterative process with the development of the gaps measurement space. Regarding creation of the warfighting foundation for the gap assessment, chapter 3, Warfighter Workshop, describes how to get the most out of the time with the warfighter to assess gaps both qualitatively and quantitatively. These assessments are then described separately in chapter 4, Gap Analysis. Chapter 5, Overall Assessment and Integration, discusses how to take the quantitative gap assessments and roll them into a single gap mitigation scale. The chapter also presents sensitivities that may be performed

[2] TRAC-H-TM-12-034, Measurement Space Code of Best Practice. TRADOC Analysis Center. June 2012.

on the quantitative assessment and describes how to integrate the qualitative and quantitative gap assessments into the overarching analyses. Chapter 6's Application Challenges paragraph addresses the challenges in implementing this approach.

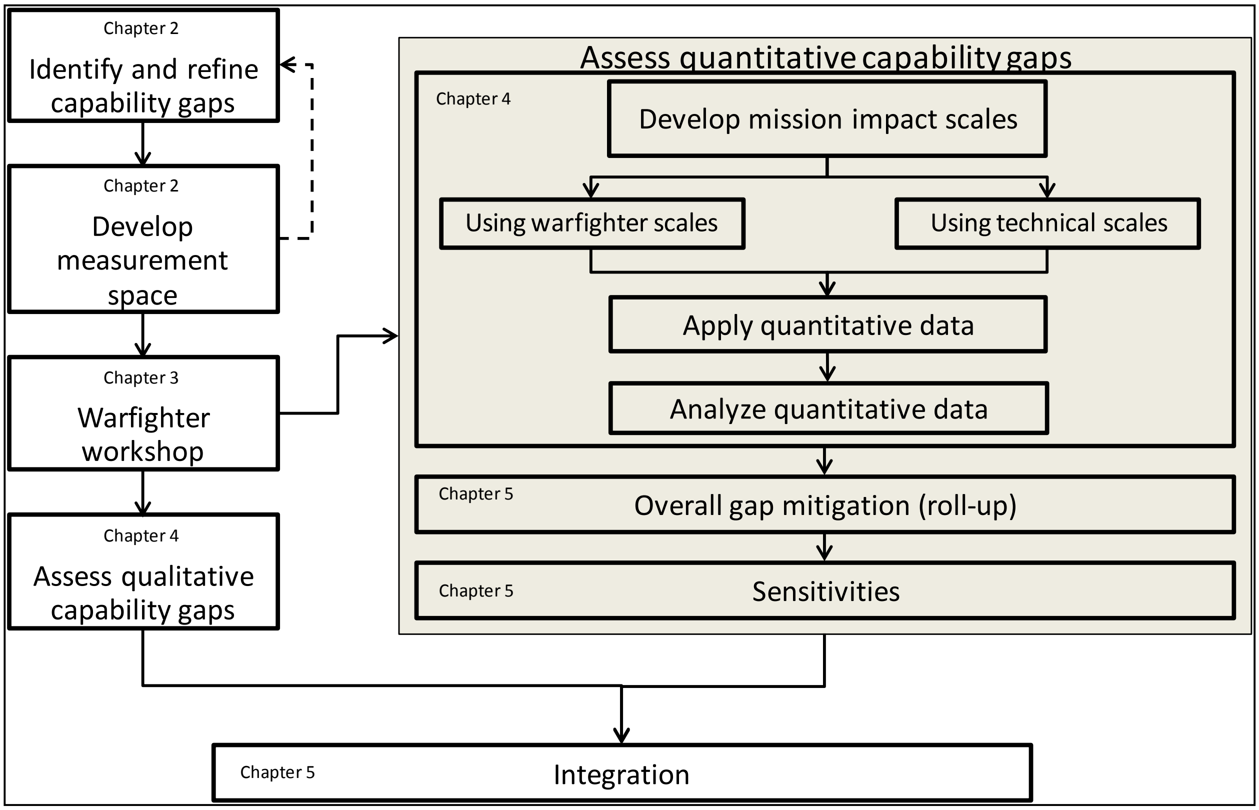


**Figure 1. Gap Assessment Approach.**

# Chapter 2
# Gap Refinement and Measurement Space

**Purpose.**

The most challenging step in gap assessment is the identification and refinement of the capability gap statements. Capability development for the Army is the responsibility of the Army Capabilities Integration Center (ARCIC). The capability needs analysis (CNA) process ARCIC uses, as an integrating agency, is intended to become the primary source for organizational gaps. At the time of this report, TRADOC Centers of Excellence (CoEs) are the appropriate initial source for capability gaps.

This chapter describes the potential gap sources, how to identify the critical elements of a gap, how to refine a gap to a level needed for assessment, how to ensure gap measurability in conjunction with a measurement space workshop, and the importance of attaining approval of the refined gaps before their assessment.

**Capability Gap Sources.**

ARCIC and TRADOC CoEs are the official sources for capability gaps. Start your search for applicable gaps through the appropriate TRADOC CoE. Official documents describing the capability gaps are the best sources, such as capability-based assessments or initial capabilities documents (ICDs). If the capability, materiel item, or subject under study is unavailable from a TRADOC CoE, identified experts must develop the capability gaps before the start of the gap assessment. Analysts should never develop the gaps. They work with the appropriate CoE or TRADOC/ARCIC directorate to identify existing capability gaps for refinement.

**Detail Required in a Capability Gap.**

Gap refinement workshops conducted with experts from the CoE are critical to ensuring detail is captured in the capability gap statements. Even if the gaps are recently created or updated through the CNA process, and even if the capability gaps meet the criteria described below, specifics to the potential solutions being studied will make the capability gap refinement critical. Never skip this step.

Capability gaps must:

- Specifically state the problem and the associated task.
- Identify what conditions cause the problem and how frequently the conditions occur.
- Describe the gap’s measurable component (a standard that describes how closure/mitigation of the gap can be measured).
- Describe the operational or tactical risk associated with the gap.

If time permits after the workshops, taking the refined gap statements to warfighters with experience on the system or capability under study can corroborate gaps and develop more detail to attain measurability.

**Threat Assessment.**

Become familiar with the System Threat Assessment Report (STAR) associated with the capability under study. This document and additional threat assessments identifying future proliferation and worldwide availability are often key components of the capability gaps. Ensure that details from the STAR and other threat assessments are incorporated into the refined gap statements. Have your threat representative document the future proliferation and worldwide availability as an indicator of frequency of the threat.

**Capability Gap Measurement Space.**

Ensure the capability gaps are identified and understood before the study's measurement space workshop. The workshop is an opportunity to identify and develop the measureable components or standards for each gap. In this document, the components/standards are called attributes. The quantifiable system characteristics (attributes) must be measurable (to a standard) and must have a valid data source to execute this gap assessment method. The workshop provides the expertise and process for these gap details. It also focuses the analytic planning toward measuring gap mitigation.

**Gap Approval.**

Following the measurement space workshop with another refinement workshop may be necessary to clarify additional questions. This refinement workshop provides focus for the CoE to approve the gaps at the colonel level. Unless the study is very-high visibility (to the Chief of Staff of the Army), colonel-level approval at the CoE is sufficient. However, additional study approval for the gaps is necessary. The study advisory group (SAG) needs to review and approve the gaps and be aware of their original source and additional refinement. Skipping SAG approval could hurt the gap assessment. See the chapter 6 Application Challenges paragraph on gap sources and approval.

**Gap Refinement and Measurement Space Results.**

Upon completion of the gap refinement process and measurement space workshop, the resulting gaps will fall under two categories for further analysis: qualitative or quantitative.

<u>Qualitative Capability Gaps.</u>

Qualitative gaps will describe a capability with attributes (measures and standards) that are not quantitative or do not have a study data source from which to compare alternatives. The language will not specifically point to a quantifiable deficiency where technical, performance, or operational data are available to compare alternatives. The gap must, therefore, be assessed qualitatively by subject matter experts/warfighters through a survey or discussion method.

For example, a capability gap describing the inability of multiple platforms to perform cooperative engagements through visual, verbal, and data communication is qualitative. The potential exists to measure cooperative actions in an operational environment through time standards or "success" criteria, such as the quantity of threats killed due to cooperative engagements. However, the measurement space workshop may inform the gap analyst that the modeling and simulations recommended for the study do not provide that level of detail. As a result, the gap's impact to the mission of not being able to cooperatively engage a target is assessable only through qualitative assessments.

Quantitative Capability Gaps.

When the gaps are quantitative, numbers or values represent the attribute and a source exists for those values through technical, performance, or operational analysis. For example, a gap describing the inability to travel fast enough in cross-country terrain has an obvious metric of miles per hour. Some, and preferably most, capability gaps are quantifiable.

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# Chapter 3
# Warfighter Workshop

**Purpose.**

The warfighter workshop represents the venue in which the study team can collect feedback and get an assessment of the capability gaps directly from the actual users: warfighters. The workshop enables the study team to distribute prepared surveys and discussion questions to which the warfighters can respond and influence the analysis. Success hinges on getting the right people with the right experience to complete the gap assessments.

**Workshop Planning.**

Following the study measurement space workshop, the study team will know which capability gaps are qualitative and quantitative in nature. The measurement space workshop should also give the study team the attributes and metrics for each quantitative gap. The team then begins the planning for a warfighter gap assessment workshop.

<u>Availability of Warfighters.</u>

The most important element of workshop planning is identifying warfighters with the right experience for the study. The next most-critical element is accessing the qualified warfighters in a timely fashion. Consideration of the number of warfighters required for defendable assessment results is important. Statistically, more than 30 data points for each question will allow insights from responses to be significant. Given that there may be some outlier responses, providing surveys to more than 40 warfighters should afford the study team defendable results. More than one warfighter workshop may be necessary because of availability and location of these experts.

There may also be more than one reason to schedule time with the warfighters, as discussed in chapter 2. You may want their expertise in reviewing the capability gaps, but at a minimum, you need their input for the gap assessment. The rest of this chapter focuses on the planning and survey development for the gap assessment warfighter workshops.

<u>Defining the Severity Scales.</u>

As chapter 1 noted, this method is grounded in the mission impact severity ratings from FM 5-19. The severity ratings are “negligible,” “marginal,” “critical,” and “catastrophic.” These terms and their meanings are familiar to warfighters. Using the FM 5-19 categories affords the study team a method to ensure warfighters are assessing each capability gap with a consistent understanding of what each severity rating means in relation to the gap.

<u>Development of Surveys.</u>

Start the survey development process with brainstorming to develop questions that can be asked of warfighters to assess the attributes coming from the measurement space workshop. Questions for the qualitative gaps should also be brainstormed so that the survey accounts for all capability gaps. Developing questions and surveys is the most crucial element of the entire gap assessment process, because poor questions will lead to insignificant results.

Some capability gaps will have multiple gap attributes associated with them, and each attribute will need a separate question. For example, the capability gap may be related to mobility, and the mobility attributes are cross-country speed, hard-surface speed, and dash speed. Once brainstorming is complete, questions should be pared and refined to be clear, concise, and straightforward. Testing the questions on military operations research analysts external to the study team can help ensure the questions are clear and answerable. Testing also allows the study team to get sample output and determine whether warfighters will interpret the questions as expected. These questions will then serve as the basis for the surveys warfighters complete during the gap assessment workshop. Not all quantitative gaps may be measured by the warfighter and will require technical expertise. Select the appropriate experts for the attribute in question and use the same techniques that follow. Chapter 6 shows a technical scale used in the same manner as the mission impact scales.

Once the survey questions are clearly identified, analysts must determine the nature of the quantifiable gap questions. Mathematically speaking, a measurement can be continuous (e.g., time or miles per hour) or discrete (e.g., number of vehicles) in nature. Each gap may have multiple metrics that may be purely continuous, purely discrete, or a mix of both. Therein lies the power of this gap assessment approach, as it provides the means to combine not only multiple continuous scales of varying metrics, but also attribute scales of varying types.

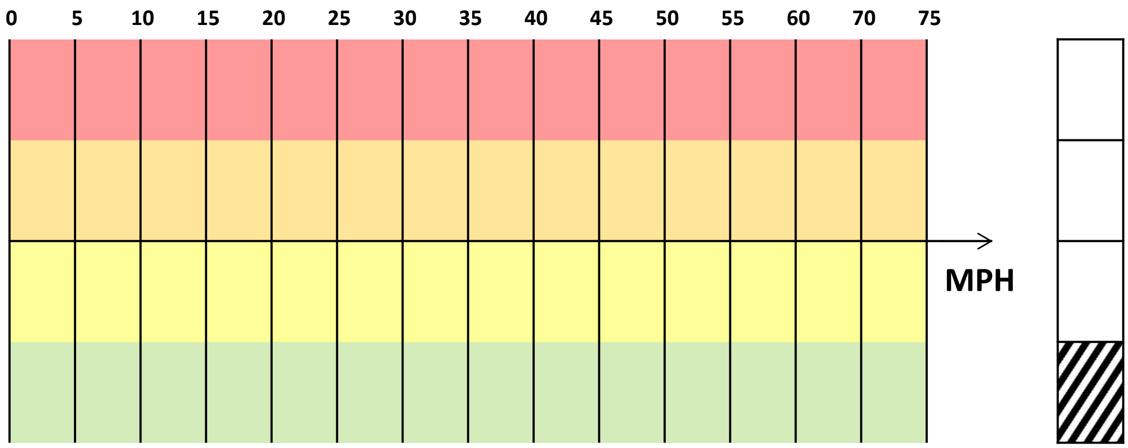
After questions for warfighters are developed and refined, the study team should begin creating the formal survey. For the attribute questions that are answerable on a continuous scale (e.g., time or miles per hour), the range of metrics that create the attribute scales should be reduced to only what is feasible for the alternatives under study. For example, the feasible miles per hour range for a combat vehicle probably does not exceed 60 or 70. An assessment of the alternative capabilities and draft requirement may assist in setting the range.

The survey tool should ask warfighters to identify the mission impact severity[3] (“catastrophic,” “critical,” “marginal,” and “negligible”) ranges for each question/attribute. Warfighters should also provide a “good enough” and an “optimal” value on the attribute scale. The “good enough” value is a point at which warfighters assess that they can sufficiently complete their mission without significant risk. The “optimal” value is the warfighter’s ideal operating value that allows completion of the mission without setbacks or hardships. These data points are compared with the capability requirements where applicable. In addition to asking respondents to identify specific values, ask for brief comments about why they chose what they did. These comments can offer insights that make the analysis more defendable in the end. An example of a continuous scale question and survey format is in Figure 2.

[3] Definitions for the severity ranges came from FM 5-19.

| Gap | Gap Contribution | Scenario | Please ✓ One | Participant # |
|---|---|---|---|---|
| Mobility | Hard Surface Speed (MPH) | Major Combat Operations (MCO) | | |
| | | Irregular Warfare (IW) | | |

❶ Indicate on the scale the points at which hard surface speed has a catastrophic, critical, marginal, and negligible negative impact on the currently discussed mission.




❷ Indicate on the scale (▲) the point at which hard surface speed (MPH) is "good enough" for the currently discussed mission. Also write value here ______

❸ Indicate on the scale (★) the point at which hard surface speed (MPH) is "optimal" for the currently discussed mission. Also write value here ______

| **Additional Comments (Insight into "good enough" and "optimal" values are especially useful)** |
|---|

______________________________________________

______________________________________________

**(Continue on back if necessary)**

**Figure 2. Continuous Scale Survey Example.**

Not all attributes can be evaluated in a continuous form. These are best answered using discrete values (e.g., number of vehicles in a platoon losing turret firepower). For consistency, use the same severity categories as in the continuous scales. This will be critical when assessing across attributes for a single gap and when assessing across multiple gaps. Unlike continuous scales, discrete scales may not warrant a "good enough" and an "optimal" value. However, comments or justifications for choices are still highly valuable. Figure 3 shows a discrete question answered in table format.

| Gap | Gap Contribution | Scenario | Please ✓ One | Participant # |
|---|---|---|---|---|
| Complex Environment | Loss of Mobility | Major Combat Operations (MCO) | | |
| | | Irregular Warfare (IW) | | |

❶ Indicate on the table (**✓)** the negative impact on mission (catastrophic, critical, marginal, or negligible) for loss of mobility in 1, 2, 3, and 4 IFVs in a platoon for the currently discussed mission. You must have only one ✓ per row, but you may have as many ✓'s per column as you like.

| **# of IFVs in Platoon Suffering Loss of Mobility** | **Impact on Mission (Please ✓ One Per Row)** | | | |
|---|---|---|---|---|
| | Catastrophic | Critical | Marginal | Negligible |
| 1 IFV | | | | |
| 2 IFVs | | | | |
| 3 IFVs | | | | |
| 4 IFVs | | | | |

| **Additional Comments** |
|---|
| |
| |

**(Continue on back if necessary)**

**Figure 3. Discrete Table Example.**

Finally, the qualitative gaps require assessment. Survey questions for the warfighter remain the best approach. While warfighters will be unable to assign a number that represents the marginal mission impact of not having enough space in their vehicle, for example, they can describe the impact in words. Survey questions developed for these gaps are best answered through written responses from the warfighters for collection and quantity-of-response purposes. Some questions may also require facilitated discussion with warfighters during the workshop. When using discussion-based questions, the best method is to have one study team member lead the discussion while other team members take notes. This allows the leader to focus on asking follow-up questions or to keep the discussion flowing. An example of a qualitative survey question format is in figure 4.

| Gap | Gap Contribution | Scenario | Please ✓ One | Participant # |
|---|---|---|---|---|
| SWaP-C, Electrical | Turret System Reboot Time (minutes) | Major Combat Operations (MCO) | | |
| | | Irregular Warfare (IW) | | |

1 Describe the mission impacts of incurring a turret system reboot. Describe in terms of a single reboot and multiple reboots per mission.

Single Reboot per mission impacts:

Multiple Reboots per mission impacts:

(Continue on back if necessary)

14

**Figure 4. Qualitative Survey Question Example.**

**Workshop Rehearsal.**

Once all inputs are developed for the workshop, select representative attendees such as military functional area (FA) 49s to rehearse workshop execution. Walk through the timing of your schedule and have your representatives ensure the survey is clear and answerable before you go to the actual workshop. Getting time with warfighters can be rare, so make the most of your effort through practice and rehearsal.

**Workshop Execution.**

Certain "must do" actions can ensure success. Begin by setting the study foundation. This is done by providing the background of the study, affirming the importance of warfighter input, and reviewing the scenario briefings to establish a similar operational environment for assessment of survey questions for all respondents. Success particularly relies on:

- Communication of the operational environment.
- Effective explanation of survey sheets.
- Logical ordering of survey sheets.
- Verification of respondent input.

Communication of the Operational Environment.
Establish the importance of the surveys to the future of the Army. This emphasizes that the time spent at the workshop is valid. Let the warfighters know that their voice will be heard. Highlight the importance of the workshop by effectively describing the capability gaps and the operational environment within the scenarios. Ensure the key features of the scenario are emphasized, allowing the warfighters to appropriately evaluate the capability gaps.

Effective Explanation of Survey Sheets.
The survey sheets, especially those with a continuous scale, are neither immediately intuitive nor overly complicated. An effective explanation about completion is crucial to establishing a common understanding among warfighters of the survey expectations. Building PowerPoint slides showing how the warfighters will fill in the survey sheets is effective. Rehearsal will help ensure proper time is allotted for each question. If time becomes an issue, ensure that valid results are your priority even if it means removing some questions.

Logical Ordering of Survey Sheets.
Surveys should be grouped for ease of understanding. They should first be grouped according to the type of scale involved. All continuous scale sheets are grouped together, followed by discrete scale sheets, and finally other types of survey questions, such as the open responses for the qualitative gaps. The purpose is to keep the warfighters accustomed to a particular method for an extended time. Surveys should then be ordered according to warfighter experience. The first sheets should contain topics with which warfighters have the most experience, such as on- and off-road speed. Topics such as lethality overmatch, for which there is significantly less experience, should be put toward the end. The purpose is to build warfighters' confidence in survey completion before asking them to think more critically.

Verification of Respondent Input.
In workshop execution, verifying respondent input while the workshop is in session is important. This allows the study team to discover anomalies in responses and verify that the respondent understood the questions. For example, at TRAC's GCV workshop, a study team member was dedicated solely to data entry, with the focus of entering all participants' scores as quickly as possible. As the data were entered, preformatted graphs were populated, allowing the team to instantaneously visualize results. Once the data were entered, the team did a quick analysis and produced a brief back to the participants to promote group discussion and gather insights into any inconsistencies in the data. This same-day processing proved to be invaluable to the team by providing an opportunity to discuss results with participants while the results were still fresh in

their minds. Inter-rater reliability statistics may be used to assess concurrence of participant answers. For the GCV implementation, graphics were used to visually identify variations. In the event participants stood out as having unusual ranges of input, the study team discussed their results during a sidebar. Refer to chapter 6's Survey Validation paragraph for some examples of outliers.

**Sensitivity Analysis Data Collection.**

In addition to gap attribute questions during the workshop, additional information to support planned sensitivities may require data collection and support from warfighters. A recommended sensitivity is for warfighters to prioritize the gaps. This should include the magnitude of importance for each capability and not a solely ordinal ranking. One method involves warfighters distributing $100 among the capability gaps, giving more money to those they deem most important to mitigate and no money for those they think are nonissues. The priorities are used during the sensitivity analysis. See chapter 5 for a discussion.

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# Chapter 4
# Gap Analysis

**Purpose.**

Deriving mission impact scales based on warfighter experience is critical to the quantitative gap assessment. This chapter describes the development of those scales and shows how data are applied to the scales to begin the gap analysis.

**Qualitative Gap Analysis.**

Qualitative gap survey results require analysis to determine which alternative offers the best gap mitigation. The analysis of qualitative responses requires the study team to parse survey responses to determine trends and commonalities. This is done by manually reading through responses and grouping those that are similar in nature. Once all responses have been categorized, the study team can record those responses that are prolific, with attention being paid to responses that suggest a feature, a capability, or a quality that might distinguish among alternatives.

**Quantitative Gap Analysis.**

Analysis of the quantitatively assessed gaps is more structured and scientific than the process for qualitative gaps. The first step is to create a database of survey responses for each question. A simple method is to manually enter survey responses into an Excel worksheet and use a new tab/worksheet for each question asked. The next step is to create the mission impact scales, as discussed in the following sections for warfighter-assessed capabilities and those assessed solely through technical data.

**Mission Impact Scales.**

<u>Warfighter-assessed Quantitative Attributes.</u>

Several steps are required to translate the results of the surveys into a single scale. Begin by creating histograms for each survey question based on the warfighter responses. Figure 5 shows an example of a histogram for the dash-speed survey question. Warfighters agreed on the severity of the mission impact at some points but disagreed on others, as the overlapping colors show. This poses a challenge in determining at what point along the scale the mission impact changes (e.g., at what point does “catastrophic” become “critical”?).

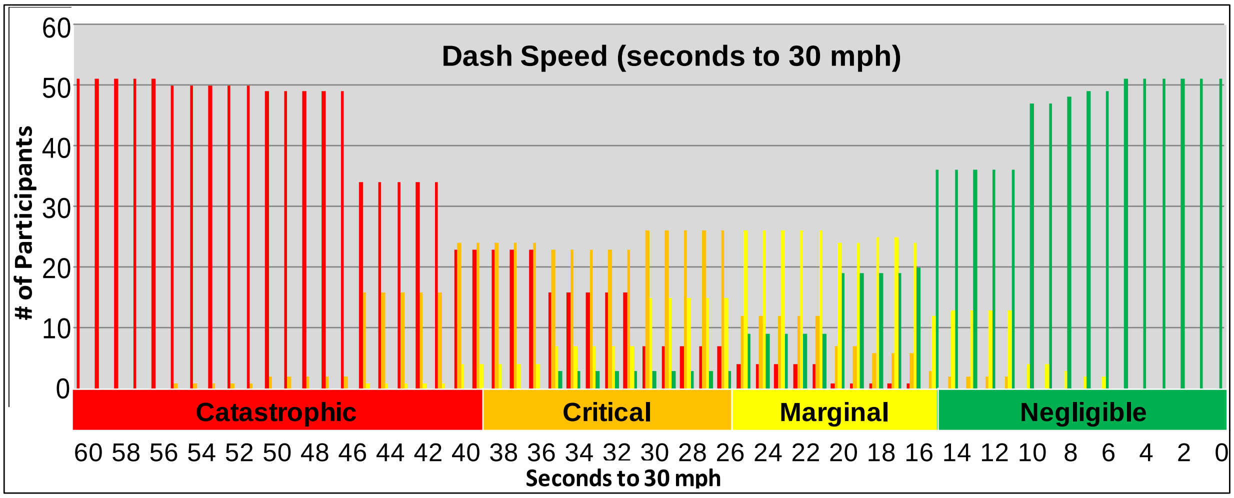



**Figure 5. Mission Impact Scale Development.**

To find these points, fit a curve to the data for each severity category ("catastrophic," "critical," "marginal," and "negligible"). Then find the intersection points of these curves. The intersection points will identify where the mission impact scale changes. To do this, fit the data for each severity category to an appropriate probability density function (PDF) using a distribution-fitting software package (a detailed discussion is in appendix A). Note, however, that when fitting the PDFs to the data, the curves will keep the shape of the histogram, but not the height. Figure 6 illustrates this height difference.

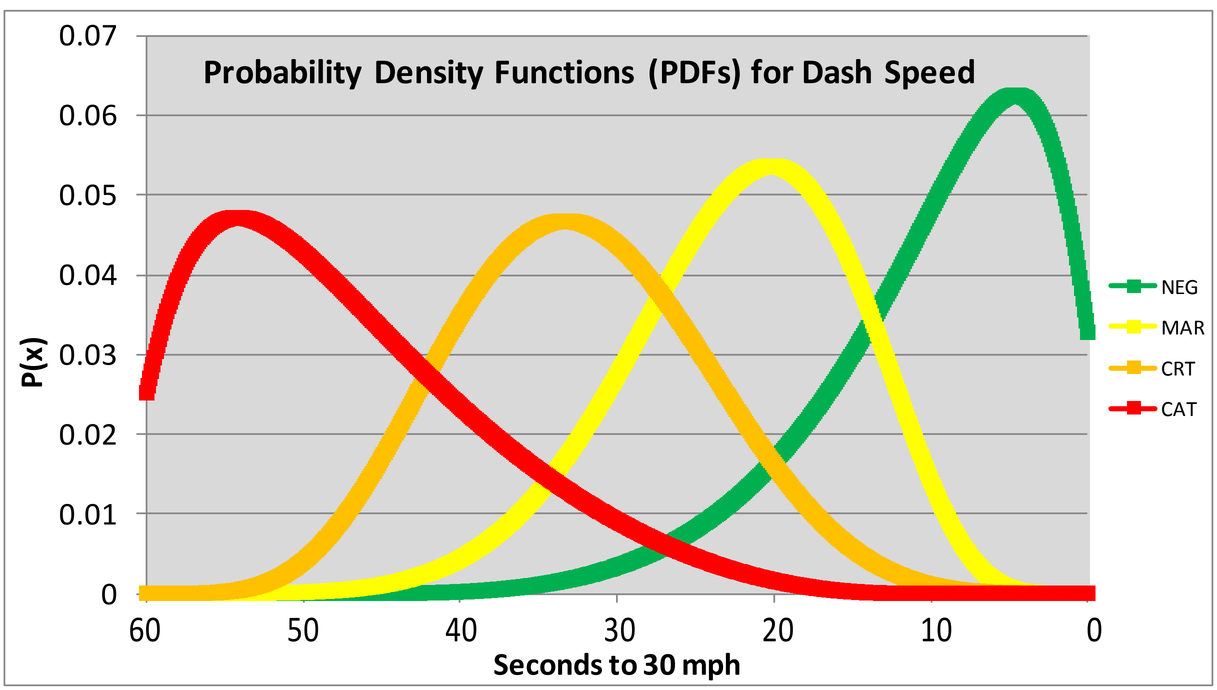



**Figure 6. Probability Density Functions.**

The red "catastrophic" severity category region in the dash-speed histogram (figure 5) has a maximum height of 51. The highest point of the red PDF in figure 6 is 0.0472. This height difference must be corrected to find the accurate transition points on the mission impact scale. A transformation scalar must be found to adjust the PDFs to the proper height. The transformation scalar is calculated using the equation in figure 7.

$$\frac{\text{max height PDF}}{\text{X}} = \frac{\substack{\text{max height of histogram} \\ \text{at the max height of the PDF}}}{\text{total \# of participants}} \rightarrow \text{X} = \frac{(\text{total \# of participants})(\text{max height PDF})}{\substack{\text{max height of histogram} \\ \text{at the max height of the PDF}}}$$

**Figure 7. Transformation Scalar Equation.**

As previously stated, the maximum height of the red PDF in figure 6 is 0.0472. At the PDF's maximum height, the histogram shows 50 of the 51 warfighters agreed. These numbers can be put into the equation in figure 8.

$$\frac{0.0472}{X} = \frac{50}{51} \rightarrow X = \frac{(51)(0.0472)}{50} \rightarrow X = 0.0481$$

**Figure 8. Transformation Scalar Example.**

This results in a transformation scalar of 0.0481. Finally, divide all points within the distribution by their respective scalar. Figure 9 shows the resulting curves. Each curve will have its own transformation scalar, so repeat this process for all severity categories.

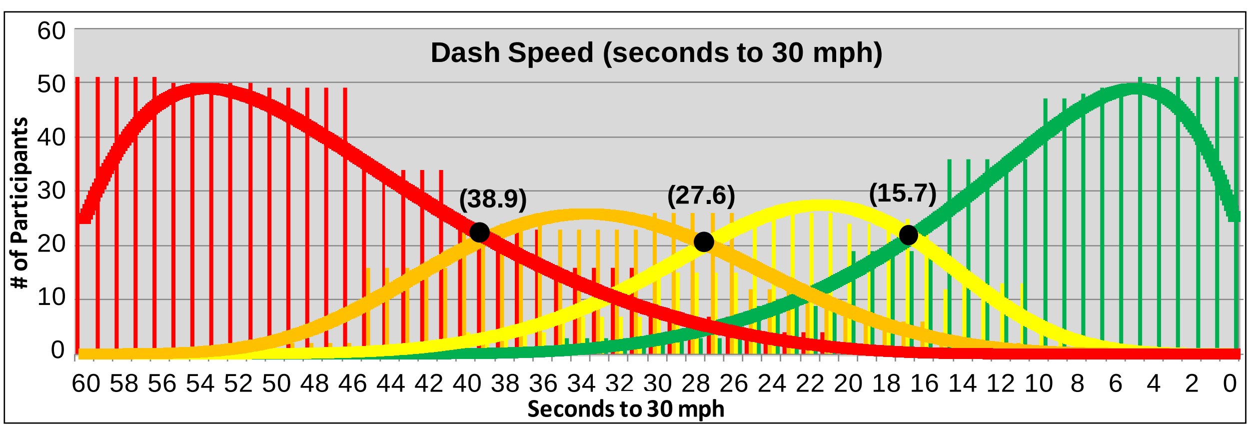



**Figure 9. Transformation Graph.**

Once the true intersection points are found, the mission impact scale in figure 10 can be produced. Note that curve fitting instead of PDF fitting is acceptable. However, fitting the PDFs can be useful in other areas. A discussion is in the "Additional Methods" section of chapter 6.

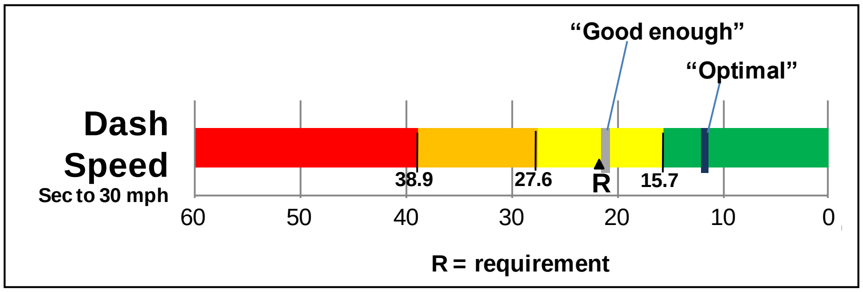



**Figure 10. Mission Impact Scale.**

Additionally, the warfighter-provided "good enough" values are averaged to determine a single "good enough" value to place on the mission impact scale (figure 10). The same process is completed for warfighter "optimal" values. Also, the capability requirement is placed on the mission impact scale. This requirement, represented as "**R"** in the figure, comes from the official capability gap documents, most typically the capability development document (CDD) or ICD. As discussed in chapter 3, the "good enough" and "optimal" values are compared to the requirement as a validation check. When inconsistency exists between warfighters' "good enough" value and the requirement, alternatives must be judged against the requirement value because of its approval in official documents. The resulting mission impact scales integrate science and experience by providing the basis for a quantitative assessment grounded in warfighter expertise.

**Data Application.**

The next step in quantitative gap analysis is data application. This involves applying technical, performance, or operational effectiveness data to the mission impact scales. Data application for capability gaps being assessed quantitatively is fairly straightforward. Technical experts or warfighter surveys have determined the mission impact scales, and the study team must now establish where each alternative being considered exists on the mission impact scales. To do this, use technical/performance data to assign a performance value to each alternative and then translate that value to the mission impact scale. For example, if "alternative 1" has a dash speed of 28 seconds to reach 60 mph, then place a symbol representing "alternative 1" on the mission impact scale for dash speed at 28 seconds. Repeat this process for all alternatives for each mission impact scale.

For clarity purposes, once data on the alternatives are applied to the mission impact scales, they become alternative assessment scales. Figure 11 is an example. The study team should also keep the gap/attribute requirement and warfighter-defined "good enough" and "optimal" values on the alternative assessment scale for analysis purposes.

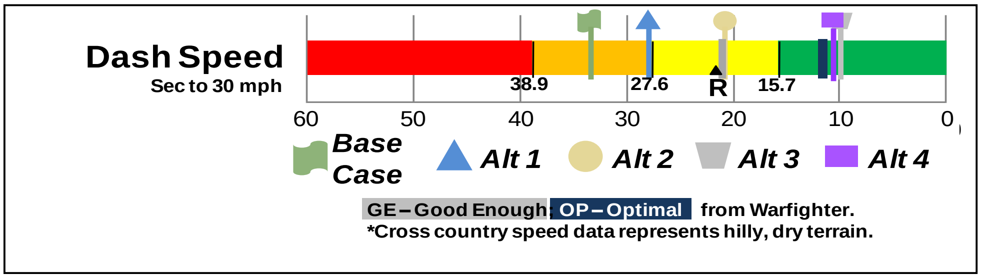



**Figure 11. Alternative Assessment Scale Example.**

**Gap Attribute Analysis.**

The next step is a comparative analysis on each capability attribute/gap. The combination of warfighter experience and scientifically assessed capabilities makes these scales powerful. They may be used to assess the following from an attribute perspective:

- "How much capability is good enough?" can be assessed by the location of the negligible part of the mission impact scale. Trade space may exist if the alternative is on the far right side of the green/negligible part.
- "Is the gap attribute mitigated?" can be determined by the alternatives in the green/negligible part.
- "By how much?" can be determined by the distance from the base case (presumed to be on the left of the scale in red, orange, or yellow) to the location of the alternatives (presumed to be to the right and in or approaching the green).

The study team can now analyze the trade space and attribute mitigation for each alternative. Figure 12 shows a sample of that analysis.

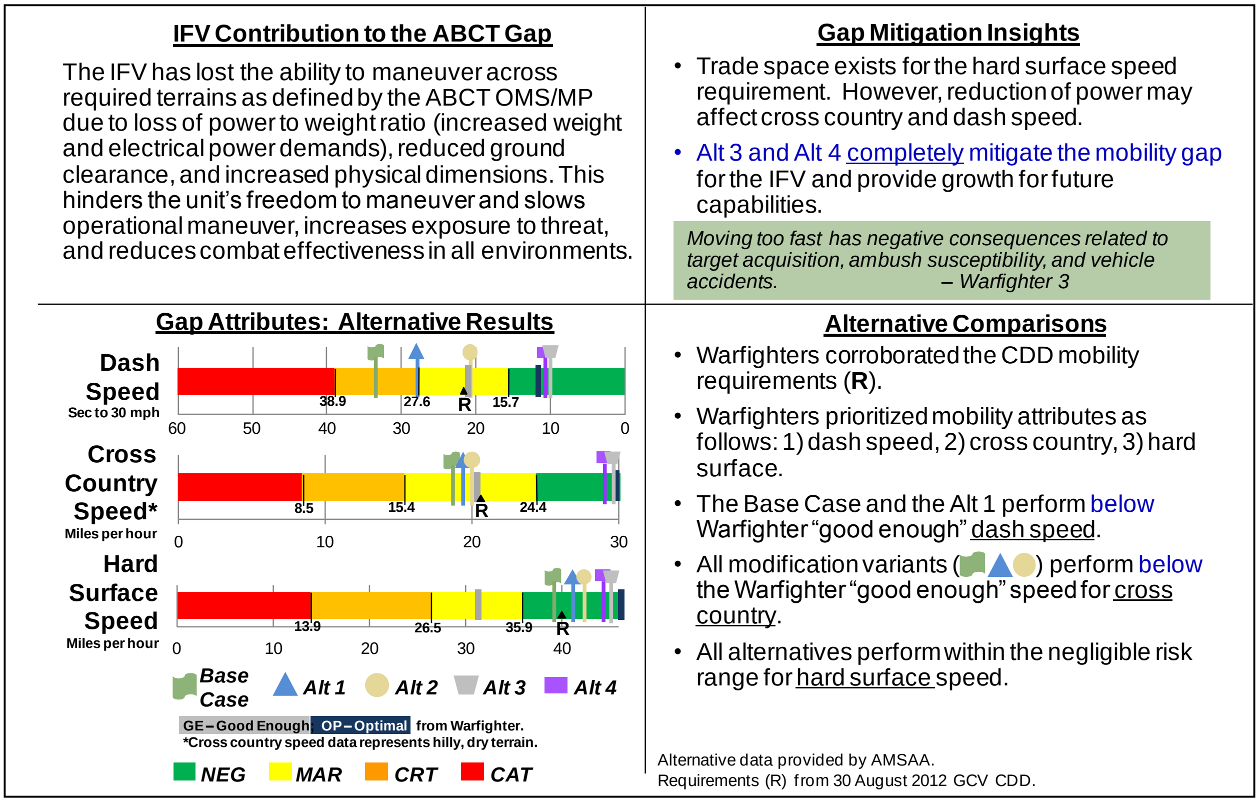



**Figure 12. Preliminary Analysis Example (Mobility Gap).**

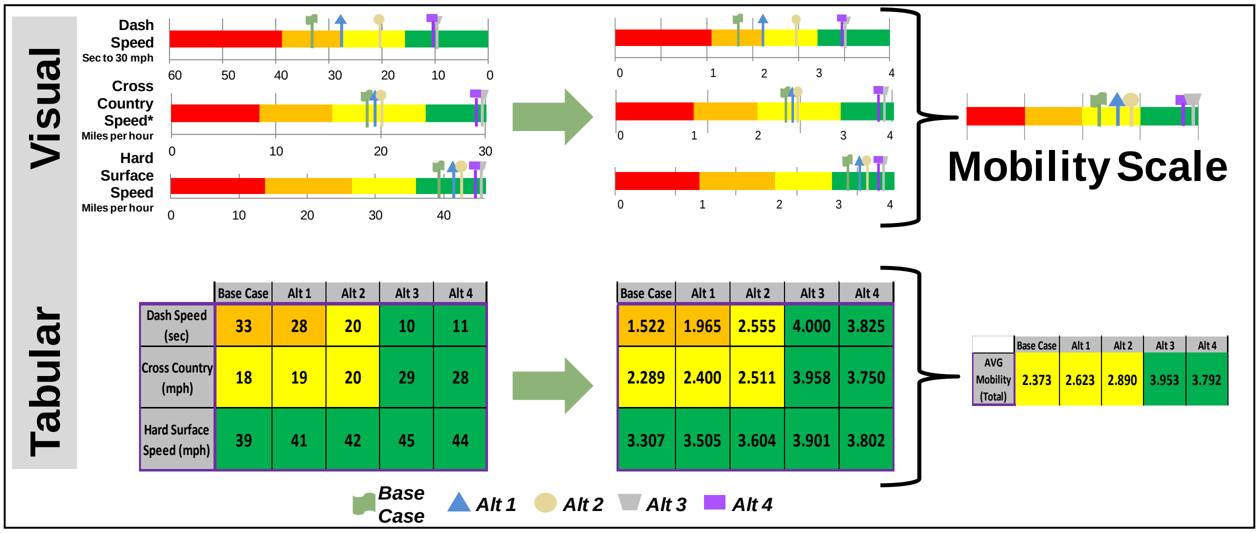
**Gap Analysis.**

The attribute analysis is informative, but it does not provide a means to answer whether the entire gap is mitigated when gaps are composed of multiple attributes. To determine the mitigation for each gap, the study team must combine the attribute-specific scales into a single scale for each gap. Combining the alternative assessment scales is not intuitive, because each scale can be based on differing metrics (e.g., miles per hour and hours of operation). Normalizing each alternative assessment scale to a common metric is the best way to address the differing metrics. The GCV study team based its normalization on this scale:

- 0-1, "catastrophic"
- 1-2, "critical"
- 2-3, "marginal"
- 3-4, "negligible"

This process assumes that the transformation follows a uniform distribution.

Normalization allows the analytic team to then combine all gap attribute scales related to the same capability gap onto a single gap scale by averaging the sum of all normalized gap attribute scores for each alternative. Examples of two methods for displaying the normalized gap assessment scales are in figure 13.




| | Base Case | Alt 1 | Alt 2 | Alt 3 | Alt 4 |
|---|---|---|---|---|---|
| Dash Speed (sec) | 33 | 28 | 20 | 10 | 11 |
| Cross Country (mph) | 18 | 19 | 20 | 29 | 28 |
| Hard Surface Speed (mph) | 39 | 41 | 42 | 45 | 44 |

| Base Case | Alt 1 | Alt 2 | Alt 3 | Alt 4 |
|---|---|---|---|---|
| 1.522 | 1.965 | 2.555 | 4.000 | 3.825 |
| 2.289 | 2.400 | 2.511 | 3.958 | 3.750 |
| 3.307 | 3.505 | 3.604 | 3.901 | 3.802 |

| | Base Case | Alt 1 | Alt 2 | Alt 3 | Alt 4 |
|---|---|---|---|---|---|
| AVG Mobility (Total) | 2.373 | 2.623 | 2.890 | 3.953 | 3.792 |

**Figure 13. Normalized Gap Analysis Example.**

The study team can now answer the same three questions regarding gap mitigation and trade space that were answered for gap attribute analysis:

- How much capability is good enough?
- Is the gap mitigated?
- If so, by how much?

For example, figure 13 shows that all alternatives offer improved mobility over the base case. Alternatives 3 and 4 are the only alternatives that have a negligible impact to mission capabilities. Both fall well into the negligible category, meaning they both offer significant growth potential or room for attribute trade space as discussed in the Gap Attribute Analysis. section of this chapter.

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# Chapter 5
# Overall Assessment and Integration

**Purpose.**

Chapter 4 discussed analyzing single gap attributes and how to roll up and analyze a single capability gap. The next logical step is to assess alternatives based on how well they mitigate the entire set of capability gaps.

**Overall Gap Mitigation (Roll-up).**

This overall assessment is done in the same fashion as the gap analysis explained in chapter 4. Each individual gap is already on a normalized scale, so that step is complete. Therefore, the individual gap assessment scales in chapter 4 must be combined into a single, overall gap mitigation scale.

Following the process described above, average the normalized individual gap scores for a single alternative. The result will be the overall mitigation score for the alternative, which will be placed on the overall gap mitigation scale. Once this process is complete for every alternative, the overall gap mitigation scale will be complete. The study team will then be able to report out which alternative most completely mitigates the capability gaps.

Similar to the discussion in chapter 4, if an alternative's overall mitigation score places it drastically to the right of the negligible region, potential may exist to reduce capabilities while still mitigating the gaps at hand. This may allow for reduction in cost or shifting of money into other capabilities whose gaps are not sufficiently mitigated. Go back and analyze the attributes driving the overall scale to the right. Figure 14 is an example of the overall gap mitigation scale:

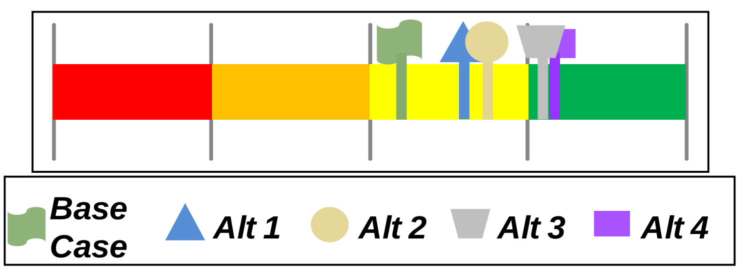



**Figure 14. Overall Gap Mitigation Scale.**

**Sensitivities.**

Even though the supposed "best alternative" has been determined, sensitivity analysis should be conducted to present the most robust analysis to decision makers. Some sensitivities to consider:

- Examine changes in gap mitigation based on changes in the operational environment by prioritizing the gaps based on their occurrence during a major combat operation or in irregular warfare environments. Prioritization may be accomplished in various ways.
  - Prioritize the capability gaps, 1 to *n*. This is easy for the analyst to incorporate into the gap mitigation workshop, while warfighters are comfortable with the requirements and the terminology of each gap. Prioritization data take little time to

collect. Ranking the capability gaps will not show how much better one gap is from another, but the analyst can weight effectively using the rank order centroid method.

  - Prioritize the gaps by assigning a dollar value. With the instructions of allocating $100 to fix these capability gaps, warfighters intuitively prioritize the gaps and give the analyst weights as well. The method requires more quality checking to make sure all dollars are used.
  - Attributes within gaps may also be prioritized. However, incorporating those attribute priorities with the gap priorities complicates the results for reporting.

- Use frequencies of gap conditions in a similar manner as the priorities described above to assess gap mitigation. However, frequencies are often difficult to identify. Refer to chapter 6's Challenges section for more information on identifying frequencies.
- Assess the significance of changes to the risk ranges by varying the location of the risk band for each comprehensive mission impact scale. This investigates how close an alternative is to crossing into a better nominal category (i.e., "negligible," "marginal," or "critical") or exceeding a very close alternative. For example: increasing vehicle protection or cross-country speed until the alternative crosses into a better nominal category or exceeds its neighbor. The amount of change is noted, cost is evaluated, and both can be reported to inform leadership.
- Assess the significance of changes (if any) in "most mitigating alternatives" based on minor changes in their total score. If two alternatives are relatively close on the comprehensive mission impact scale, performing sensitivities on the gap assessment scales to determine the impacts on the comprehensive scale may show what would have to change in the lesser capable alternative to make it exceed the other alternative(s). The same could be done on the mission impact scales that roll up into the gap assessment scales. At this level of detailed sensitivities, capability trade space may be identified.

**Integration.**

Normally, gap assessments are completed as a sub-element of a larger study, such as an AoA. Integrating the gap assessment results with the rest of the overarching analysis involves two key steps. Step one looks at emerging and final results from the rest of the study's analytic efforts and integrates those results with the attribute findings. Step two looks at the reporting formats and creates a consistent method of presentation that does not conflict with the other study's analytic efforts.

<u>Step One.</u>

For both quantitative and qualitative gaps, look at the other study analyses and determine what insights from those efforts help further explain or support each alternative assessment scale. For example, the quantitative attribute represented by the scale may be performance-based, such as cross-country speed. However, there may be operational impacts related to that attribute that are available in other analyses. Highlighting the operational impacts associated with the attribute is a critical insight to add (and source) for the gap analysis.

<u>Step Two.</u>

Format is critical when integrating the gap assessment results with the rest of the study effort. The information must flow without conflicting with other information. This gap assessment

method provides information for each gap that, when analyzed, may be presented in different ways to fit the flow. Examples of methods are:

- Visual method. Figure 13's visual method of presenting the alternative assessment scales (by attribute or by gap) and the overall gap mitigation scales (across gaps) is effective because one glance can show where the alternatives fall on a mission severity scale (mission success to mission failure), how they compare with the current capability (the base case), and how they compare with one another. However, the color schemes used for the mission severity categories may conflict with other color scales presenting other sub-analyses of the study.
- Tabular method. Using figure 13's tabular method, values instead of colors may be used to represent the mission severity scale values for each of the alternatives. This is discouraged, because the scale values are difficult to explain. High-level decision makers prefer seeing values that represent metrics of capabilities rather than categories of severity.
- Insights method. This method lists the analytic insights found when using the scales to compare the alternatives to one another, to the baseline, to a "good enough" capability or existing requirement, or to an objective goal for that gap. See figure 12 for examples.
- Percent improvement method. Figure 1's percentage improvement method works in most cases. Percent improvements are calculated as the improved data point divided by the base case data point. Percent improvements may be calculated for:
  - warfighter-identified "good enough" and/or "optimal" values.
  - threshold or objective CDD requirements values.
  - study alternatives.

The percent improvement presentation method may also be used to identify how much improvement certain alternatives are above the "mission success" start point. This will help in understanding how much more capability is achieved over the potential minimum requirement for mission success – which may become potential trade space.

**Table 1. Percent Improvement Example.**

| Gap | | | | | | | PERCENT "IMPROVEMENT" | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Base Case | Alt 1 | Alt 2 | Alt 3 | Alt 4 | | Alt 1 | Alt 2 | Alt 3 | Alt 4 |
| **Force Protection - Avg P(k)** (Smaller is better) | 0.182 | 0.179 | 0.089 | 0.021 | 0.02 | | 2% | 51% | 88% | 89% |
| **Vehicle Survivability - Avg P(k)** (Smaller is better) | 0.379 | 0.376 | 0.378 | 0.19 | 0.175 | | 1% | 0% | 50% | 54% |
| **Lethality Overmatch - meters** (Bigger is better) (negative shows threat outranges alternative) | -717 | -596 | -600 | -650 | -60 | | 17% | 16% | 9% | 92% |
| **Dash Speed - seconds to reach 30 mph** (Smaller is better) | 33 | 28 | 21 | 10 | 11 | | 15% | 36% | 70% | 67% |
| **Cross Country Speed - miles per hour** (Bigger is better) | 18 | 19 | 20 | 29 | 28 | | 6% | 11% | 61% | 56% |

## Results.

Regardless of the presentation method used when integrating the overall study results, none of the visual methods identified above can replace the real analysis required in gap assessment. Developing the scales and placing the alternatives appropriately on them is not enough to be considered gap analysis. The alternative assessment scales and overall gap mitigation scales are

only the beginning of understanding the gap mitigation potential of the alternatives or the level of capability required to mitigate capability gaps. This gap assessment method merely assists the analyst in garnering greater quantitative and qualitative information from valid sources to analyze the gaps.

# Chapter 6
# Conclusion

**Purpose.**
This chapter highlights the challenges and the potential problems with this new gap assessment approach and reemphasizes the potential uses.

**Challenges.**
The following paragraphs relate to specific chapters or paragraphs previously discussed.

Gap Sources.
Finding the appropriate gaps for study is not as easy as chapter 2 may indicate. Often, due to changes in authors or responsible organizations, gaps documented in the ICD and CDD do not match. The best resolution is to crosswalk the documented gaps with those most recent from ARCIC's CNA process.

Gap Condition Frequency.
Gap condition frequencies are often difficult to define. As documented in TRAC's Operational Risk Analysis: A New Approach (TRAC-F-TR-13-026**)**, identifying frequencies is difficult. The *Operational Risk Analysis* report identifies the following obstacles:

- History is often not a good predictor. According to Dr. Nassim Taleb's book, *The Black Swan*, using historical data to determine far-reaching, future events is often very inaccurate.
- Point of view matters. Warfighters who have found creative ways to carry out missions may find the frequency of a capability gap to be zero when soldiers who experience better capabilities understand that the current capability is inadequate and the capability gap is seen as occurring more often.
- Finding qualified experts is difficult. Placing quantitative values on frequencies depends on the experts and the type of frequency being defined. In the same manner used in this report to develop survey questions that the warfighter can address (see chapter 3), care must be taken in developing frequency surveys. It must be a reasonable question the experts can answer based on their expertise.

A strength of this new gap assessment methodology, versus most operational risk methods, is that frequency may be treated as a sensitivity and is not a necessity for determining gap mitigation. Refer to chapter 5's Sensitivities paragraph for a description of using frequencies.

Gap Approval.
Ensure the source gaps are approved before refinement, if possible, by the SAG. The capability gaps are the foundation for all analysis and the basis by which the Office of the Secretary of Defense (OSD) and DA will assess mitigation and make critical acquisition decisions. During the GCV AoA, the gaps were not briefed to the SAG or OSD/DA action officers until after the gap assessment was complete. At that time, OSD representatives stated that "the only approved gaps are those in the ICD." As a result, the reporting was done based on the ICD gaps that were not refined. The gap assessment documentation in the report appendix had to explain the use of the armored brigade combat team gaps and how they linked back to the "official" ICD gap statements.

Survey Validation.

An interesting result of the survey sheets, especially continuous scale, is that warfighters may complete the risk scales opposite to what the study team is expecting. For example, a respondent might judge higher off-road speeds to be associated with higher risk. The problem is that the result cannot be used according to the methodology. In these cases, the study team should point out the result to the respondents and ask whether they understand the question. If the respondents remain adamant that their response is correct, then the study team should acknowledge their point of view and designate the data as an outlier. Although losing a data point because it contradicts the CDD requirements is disappointing, insisting that warfighters adhere to the logic of the CDD could damage their confidence in the workshop.

Gap Prioritization.

The GCV AoA prioritized the gaps within two different scenarios – a major combat operation and an irregular warfare context. In hindsight, the preference is prioritization across any or all scenarios. A single priority across all scenarios is easier to perform sensitivities on and easier to explain to decision makers. Because the prioritization occurred before this gap assessment methodology was developed, the complexities experienced could not be foreseen. Keeping all prioritizations and sensitivities simple allows easy explanations of gap results.

Technically Defined Scales.

Not all gap attributes are appropriate for warfighter-developed scales as discussed in chapters 3 and 4. In some instances, a comparable scale may come from technical experts. For example, probability of kill ($P_k$) data are typically available, but to ask the warfighter about partial losses of personnel or vehicles is unreasonable. The performance analysis experts, such as Army Materiel Systems Analysis Activity (AMSAA), have scales that equate partial losses to severity scales. These technical scales may be used in place of warfighter scales, if they are comparable. Refer to table 2 for an example of technical scale and mission impact scale compatibility.

Other instances exist in which technical/operational data take into account a more holistic view, and asking warfighters would give the study team an unnecessarily narrow assessment. If using purely technical/operational data, the technical experts should provide severity categories that the study team can translate into the FM 5-19 severity categories used in warfighter surveys. These scales are integral in the success of the new assessment method. If, despite measurability, warfighter-informed or technical data scales are not definable, analysts are forced to use the qualitative approach.

Additional Methods.

Other methods, in addition to PDF fitting, could be appropriate to find the transition points on the mission impact scale. Two promising methods are the averaging method and using curve fitting instead of PDF fitting.

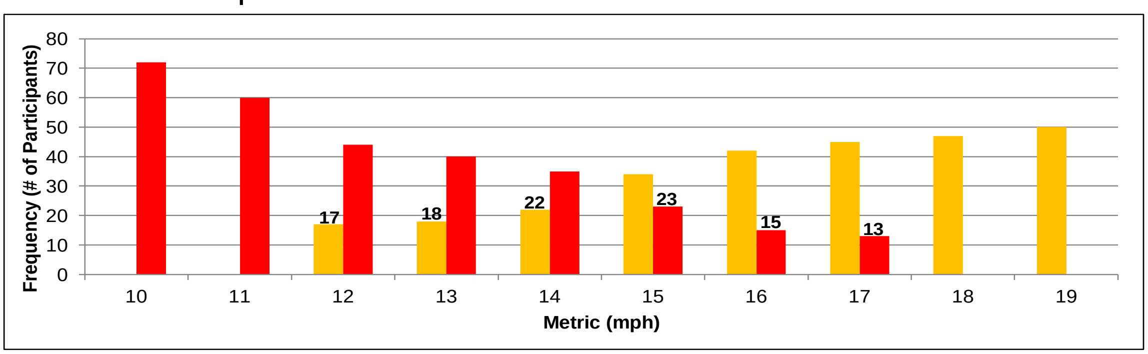
The averaging method involves taking the average of the overlapping areas on the survey response histograms. A notional example is in figure 15. However, it still involves finding an intersection or transition point, using the areas of overlap.

**Table 2. Comparable Technical and Mission Impact Scales.**

| Technical Scale Definition | Technical Scale Category | Mission Impact Scale Category | Mission Impact Scale Definition |
|---|---|---|---|
| The vehicle sustains little to no damage, and there is no loss of functionality due to impact from threat munitions. | No loss of function. | Negligible | Mission failure unlikely. |
| The vehicle damage results in a slightly decreased performance for a single capability. | Limited loss of function or slight decrease in functionality. | Marginal | Mission failure possible. |
| The vehicle damage results in moderate decrease in performance for multiple key capabilities. | Significant loss of functions or decrease in functionality. | Critical | Mission failure likely. |
| The vehicle damage results in complete, or nearly complete, loss of function for one or more key capabilities. Vehicle may even be considered unrepairable. | Severe to total loss of functions. | Catastrophic | Mission failure nearly certain. |

• Method: $Intersection\ Point = \dfrac{Sum[(Metric) * (Frequency)]}{Sum(Frequency)}$

• Notional Example:




$$Red \cap Orange = \frac{(12*17)+(13*18)+(14*22)+(15*23)+(16*15)+(17*13)}{17+18+22+23+15+13}$$

$$Red \cap Orange \approx\ 14.37$$

**Figure 15. The Averaging Method.**

Another method, as mentioned in chapter 4, is curve fitting instead of PDF fitting. Similar to the PDF method, it involves finding the intersection point of two curves. This can be done with a curve-fitting software package.

Both methods would likely be appropriate for finding the transition points between severity categories. The analyst, however, loses the flexibility of having the probability distribution for each category on the mission impact scale. Recall that the gap attribute scores were based on the assumption of uniformity. The team could benefit from exploring the use of cumulative

distribution functions (found from fitting the probability distributions in chapter 4) to generate these scores. This may offer a more precise comparison of the alternatives.

Study Integration.
Integrating the gap assessment into the overarching study effort begins at the study planning phase. Consideration should be made then regarding the severity categories (how many and their definitions). Those categories and their definitions should be coordinated across the overall study effort. If this is not done, the potential exists to do a lot of work but then be unable to use the alternative assessment scales in the final results because the color schemes and severity category definitions conflict with other sub-analyses.

**Summary.**
As the Army faces more fiscal constraints, Defense and Army officials will continue to ask:

- Is there a capability gap?
- How much military capability is good enough?
- What is the operational impact of the capability gap?
- Is the capability gap mitigated? If so, by how much?

This new gap assessment approach provides a foundation to address these questions as well as:

- Corroborating or helping refine capability requirements by comparing the threshold and objective requirements with the warfighter-identified "good enough" and "optimal" values.
- Identifying potential trade space in requirements and capability attributes by looking at differences in the above or between the alternative's value and the "good enough" values.
- Assessing the operational impact or operational risk of capability gaps and their potential solutions by comparing the base case and alternative values to the defined mission impact categories of catastrophic (red), critical (orange), marginal (yellow), and negligible (green).

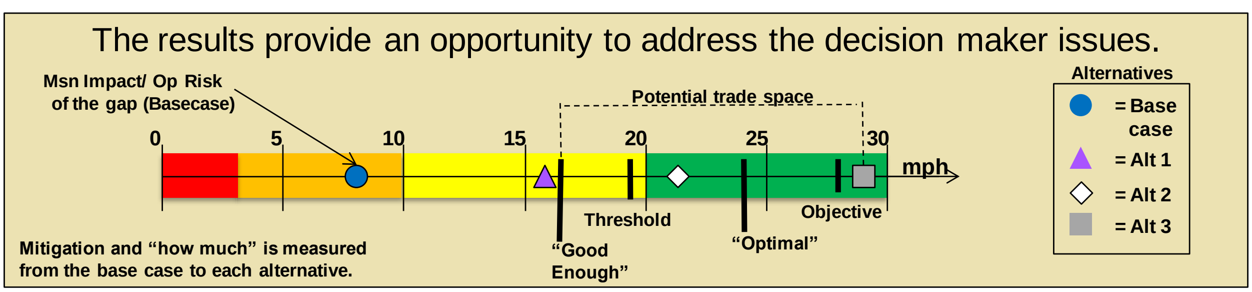
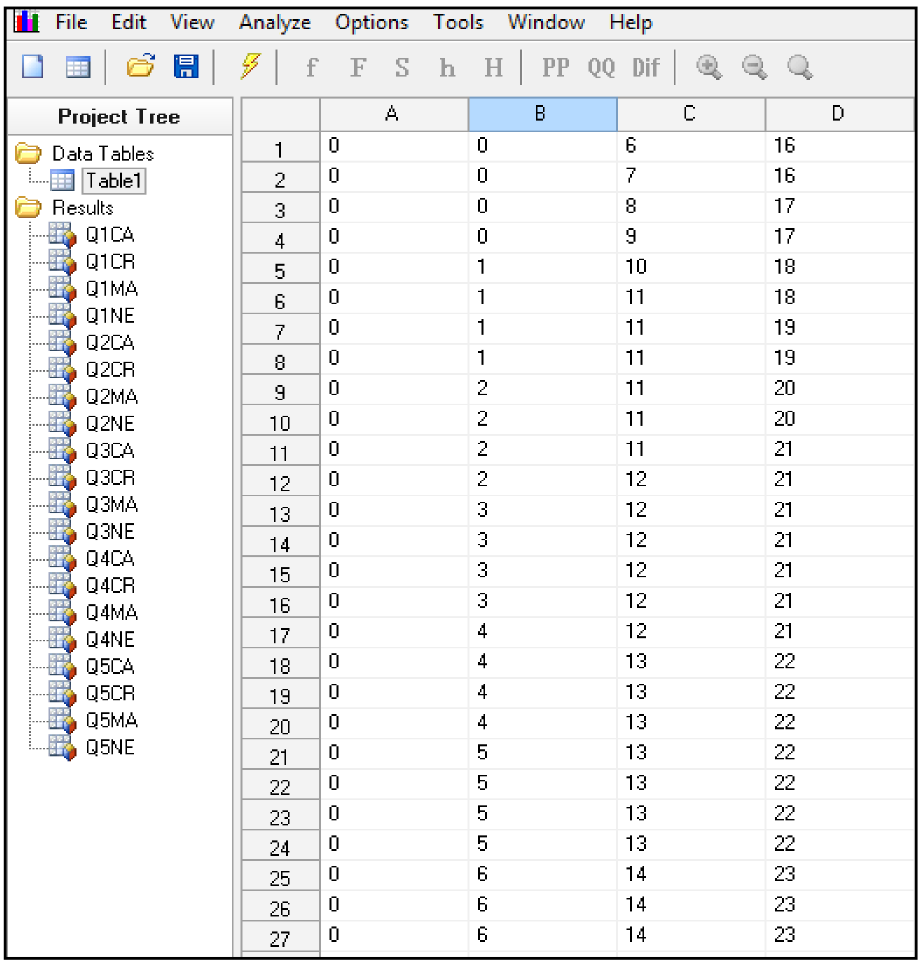



**Figure 16. Sample Results to Address Decision Maker Issues.**

# Appendix A
# Software and Tools

To fit the data to probability distributions discussed in chapter 4, the study team used EasyFit software by MathWave Technologies. Data were input for each category (“catastrophic,” “critical,” “marginal,” and “negligible”) on the mission impact scale and processed with the EasyFit package. Figure A-1 shows how the data are input into the software in a spreadsheet format.




| | A | B | C | D |
|---|---|---|---|---|
| 1 | 0 | 0 | 6 | 16 |
| 2 | 0 | 0 | 7 | 16 |
| 3 | 0 | 0 | 8 | 17 |
| 4 | 0 | 0 | 9 | 17 |
| 5 | 0 | 1 | 10 | 18 |
| 6 | 0 | 1 | 11 | 18 |
| 7 | 0 | 1 | 11 | 19 |
| 8 | 0 | 1 | 11 | 19 |
| 9 | 0 | 2 | 11 | 20 |
| 10 | 0 | 2 | 11 | 20 |
| 11 | 0 | 2 | 11 | 21 |
| 12 | 0 | 2 | 12 | 21 |
| 13 | 0 | 3 | 12 | 21 |
| 14 | 0 | 3 | 12 | 21 |
| 15 | 0 | 3 | 12 | 21 |
| 16 | 0 | 3 | 12 | 21 |
| 17 | 0 | 4 | 12 | 21 |
| 18 | 0 | 4 | 13 | 22 |
| 19 | 0 | 4 | 13 | 22 |
| 20 | 0 | 4 | 13 | 22 |
| 21 | 0 | 5 | 13 | 22 |
| 22 | 0 | 5 | 13 | 22 |
| 23 | 0 | 5 | 13 | 22 |
| 24 | 0 | 5 | 13 | 22 |
| 25 | 0 | 6 | 14 | 23 |
| 26 | 0 | 6 | 14 | 23 |
| 27 | 0 | 6 | 14 | 23 |

**Figure A-1. EasyFit Data Entry Format.**

Once data are entered, the software will fit them for each category to 42 continuous distributions or 8 discrete distributions. It will automatically output a graph for each distribution and allow the user to look at several distributions on one graph for comparison.

Figure A-2 shows a sample of output for the Johnson System Bounded (SB) probability distribution.

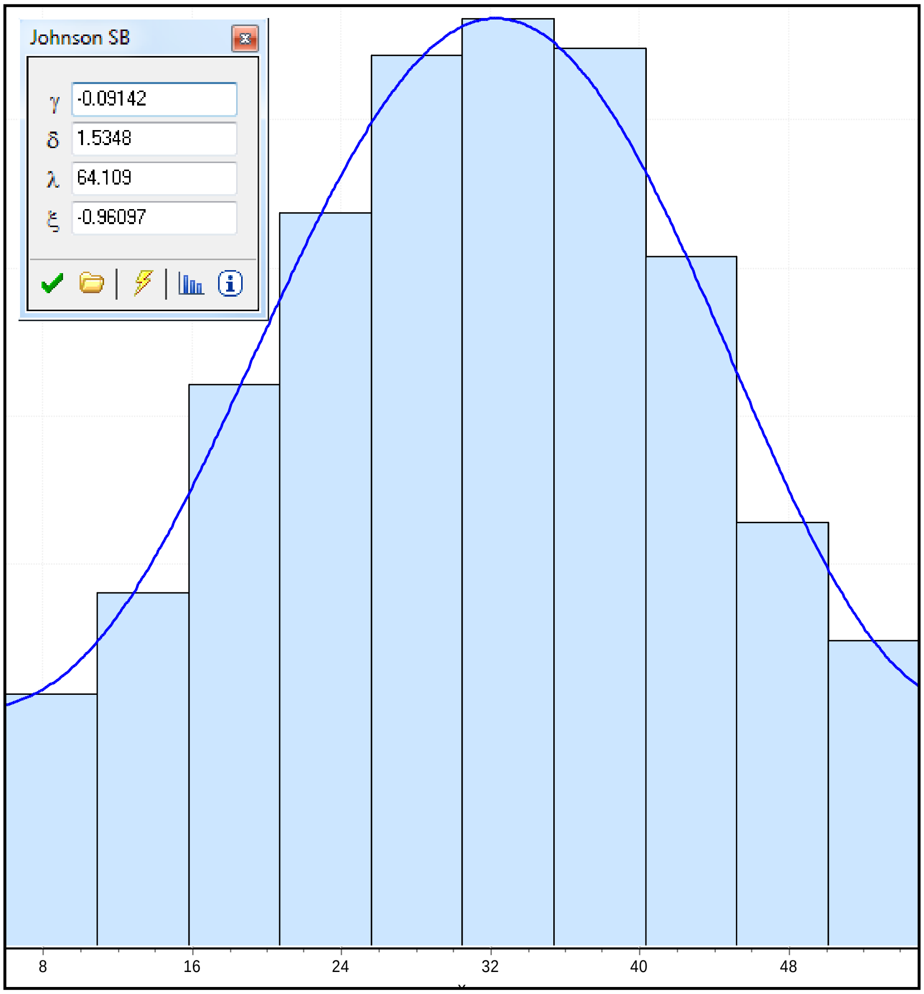



**Figure A-2. EasyFit Distribution Output.**

In addition to providing visual representations of the distribution fits, EasyFit performs three goodness-of-fit tests (Kolmogorov-Smirnov, Anderson-Darling, and Chi-Squared) for each distribution so the most appropriate distribution can be identified. Figure A-3 shows the results of these tests for the Johnson SB distribution that was fit in figure A-2.

| Goodness of Fit - Details [hide] | | | | | |
|---|---|---|---|---|---|
| **Johnson SB** [#30] | | | | | |
| Kolmogorov-Smirnov | | | | | |
| Sample Size<br>Statistic<br>P-Value<br>Rank | 1014<br>0.0239<br>0.60002<br>2 | | | | |
| α | 0.2 | 0.1 | 0.05 | 0.02 | 0.01 |
| Critical Value | 0.0337 | 0.03841 | 0.04265 | 0.04767 | 0.05116 |
| Reject? | No | No | No | No | No |
| Anderson-Darling | | | | | |
| Sample Size<br>Statistic<br>Rank | 1014<br>0.54764<br>2 | | | | |
| α | 0.2 | 0.1 | 0.05 | 0.02 | 0.01 |
| Critical Value | 1.3749 | 1.9286 | 2.5018 | 3.2892 | 3.9074 |
| Reject? | No | No | No | No | No |
| Chi-Squared | | | | | |
| Deg. of freedom<br>Statistic<br>P-Value<br>Rank | 9<br>11.222<br>0.26081<br>3 | | | | |
| α | 0.2 | 0.1 | 0.05 | 0.02 | 0.01 |
| Critical Value | 12.242 | 14.684 | 16.919 | 19.679 | 21.666 |
| Reject? | No | No | No | No | No |

**Figure A-3. EasyFit Goodness of Fit Tests.**

Once the distribution was selected for each category, the probability density functions were extracted, and the breakpoints described in chapter 4 could be found. More information on the EasyFit software is at http://www.mathwave.com/easyfit-distribution-fitting.html.

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# Appendix B
# Glossary

| | |
|---|---|
| ABCT | Armored Brigade Combat Team |
| alt | alternative |
| AMSAA | Army Material Systems Analysis Activity |
| AoA | analysis of alternatives |
| ARCIC | Army Capabilities Integration Center |
| avg | average |
| BN | battalion |
| cat | catastrophic |
| CDD | capability development document |
| CNA | capability needs analysis |
| CoE | Center of Excellence |
| CRM | composite risk management |
| crt | critical |
| DA | Department of the Army |
| deg | degree |
| FA | functional area |
| FM | Field Manual |
| GCV | Ground Combat Vehicle |
| GE | good enough |
| ICD | initial capabilities document |
| IFV | Infantry Fighting Vehicle |
| IW | irregular warfare |
| JCIDS | Joint Capabilities Integration and Development System |
| mar | marginal |
| max | maximum |
| MCO | major combat operation |
| mph | miles per hour |
| msn | mission |
| neg | negligible |
| OIF | Operation Iraqi Freedom |
| OMS/MP | Operational Mode Summary Mission Profile |
| OP | optimal, operational |
| OSD | Office of the Secretary of Defense |
| PDF | probability density function |
| $P_k$ | probability of kill |
| R | requirement |
| SAG | study advisory group |
| SB | system bounded |
| sec | second |
| STAR | System Threat Assessment Report |
| SWA | Southwest Asia |
| SWaP-C | size, weight and power - cooling |
| TRAC | U.S. Army TRADOC Analysis Center |
| TRADOC | U.S. Army Training and Doctrine Command |

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